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An investigation into blood clot removal in human vessels using the GP Mechanical Thrombectomy Device (GPMTD)

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ABSTRACT:
Blood clots may occur in vessels like arteries and veins, being the strokes one of the commonest cause of death and severe disability; deep vein Thrombosis is also a common problem. In this pilot study we investigate the effect of removing a blood clot in a dissected human vein with a novel thrombectomy device. Following successful simulations of the device, we show using histological staining techniques, that the removal of a clot by this novel device, does not cause any apparent damage to the vessel wall, when suction pressures of up to 85kPa are applied. We conclude that this device may potentially be very useful as a blood clot removal device in human vessels.

Keywords: Blood clot removal, Histopathology, Thrombectomy, Arteries, Veins, Deep Vein Thrombosis, Stroke

INTRODUCTION

Blood clots may occur in vessels e.g. arteries and veins (giving rise to Strokes and Deep Vein Thrombosis). Stroke is the third commonest cause of death in the UK with 53,000 deaths in 2007 [1] and can cause severe disability, with 40% of cases left with severe impairment [2]. Deep vein Thrombosis (DVT), is also a common problem. The exact number of people affected by DVT/PE is not known, however estimates range from 300,000 to 600,000 (1 to 2 per 1,000, and in those over 80 years of age, as high as 1 in 100) per annum in the United States. Estimates also suggest that 60,000-100,000 Americans die of DVT/PE [3].

Treatments for DVT include anti-coagulants such as warfarin and interventional methods such as percutaneous mechanical thrombectomy devices e.g. the Amplatz; Bacchus Fino device; the Arrow-Trerotola percutaneous thrombolytic device [4]. Although acute thrombolytic treatment has been shown to be a highly effective interventional method, it can be associated with a risk of bleeding and is contraindicated in pregnancy, after trauma, or postoperatively [5]. Mechanical Thrombectomy Devices (MTDs) have increased in use and have been shown to restore blood flow in patients suffering from thromboembolic stroke [6]. Such devices include e.g. the MERCI (Mechanical Embolus Removal in Cerebral Ischemia) [7], the penumbral device [8].

Other examples include rheolytic catheters (Angiojet) [9]. However, devices may carry a potential risk of breakage of moving parts, some potential risk of penetration of the vessel wall, and downstream embolisation due to fragmentation of the clot. Another thrombo-mechanical extraction device being developed is called the GPTAD (GP Thrombus Aspiration Device). A schematic view of the GP MTD, is shown in figure 1 [10-11]. The device may potentially reduce the risk of downstream embolization (since it does not have to touch the clot or insert into the clot to facilitate clot removal). It also has no moving parts (thereby potentially reducing the risk of breakage), and in-vitro studies [12] have shown that it potentially reduces the risk of clot fragmentation compared to using a straight tube without any helical configuration.

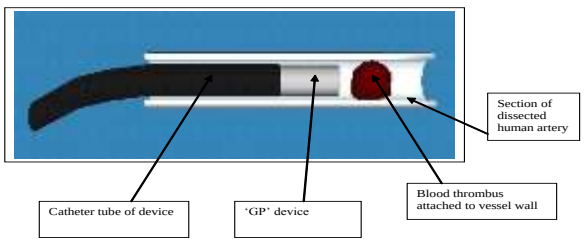

Fig.1 The GPTAD

The device has been mathematically designed and optimised, using techniques including Bond Graph

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modelling, and CFD modelling [13]. Figure 2 below shows an example of the type of modelling undertaken with CFD and shows the distribution of forces (typical pressures used) in the GPTAD itself during clot removal simulation of a blood clot of diameter about 3mm occluding a vessel [14].

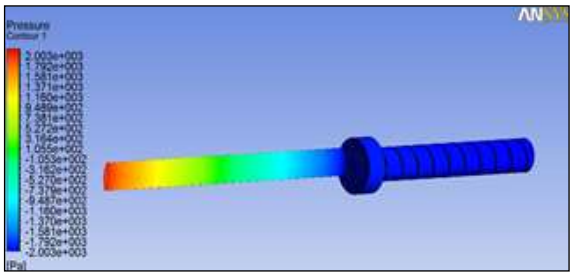

Fig.2 CFD Simulation of the GPTAD. (Romero et al 2014). Reproduced with kind permission: UKSIM Proceedings, ISBN 978-1-4799-4923-6, pp100-104.

METHODS AND MATERIALS

The study was undertaken with ethical approval having been granted by the NHS LREC (LREC reference number 07Q2702/23). Materials: GP Mechanical Thombectomy Device with an internal diameter of 1 mm at the tip (GP MTD, Dresden, Germany) (figure 1); a suction pump with a pressure range of 0-100 kPa (Welch model number 2622C-02, Gardner Denver, Sheboygan, Wisconsin, USA); Vacuum flask. The apparatus used is shown in figure 3.

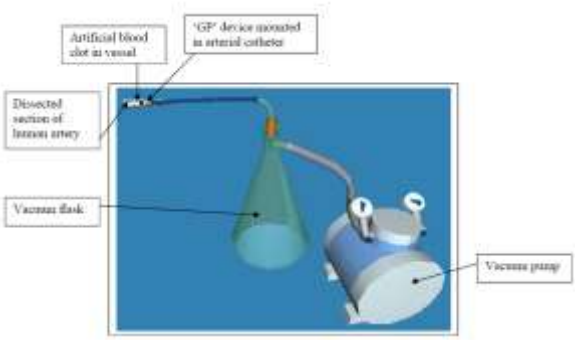

Fig. 3 The Apparatus used in the Experiments

A freshly dissected popliteal vein (the amputated limb had been removed a few minutes before) was used and the 1mm internal diameter GPTAD was passed along the 4 mm wide vein. The tip of the GPTAD was positioned 3mm proximally from a clot. Pathological sections of the vein wall were taken (i) at the point where suction of the clot had been undertaken at 18mm from the open end of the vein and (ii) at points of direct suction onto the vein wall (middle part of vein) (sucking for 30seconds at a pressure of 85kPa), and (iii) at a distal point on the vein wall where no suction had taken place. The latter served as a control.

Previous sections were processed (as routine histological material embedded in paraffin blocks and 5 micron sections were cut and embedded on the glass slides for histological examination). The sections were examined for any damage (caused by suction with the GPTAD) using Elastic Van Gieson staining, and Immunoperoxidase staining for type IV collagen. Technique for Collagen IV. (Benchmark XTT IHC/ISH staining module courtesy of the Department of Histopathology, Manor Hospital, Moat Road, Walsall WS2 9PS). The Van Gieson stain may be found in document number SOP Number SS 28 pages 1 to 6 edition number 3.0, Walsall Hospital NHS Trust.

RESULTS

Following figures presents different results after the use of the GPTAD with different conditions. In these figures, a 250 zoom factor has been used and the 'A' note indicates the site of the applied suction.

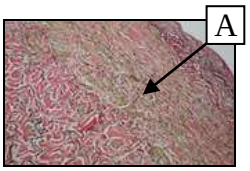

Fig.3 Section of vein at the site of clot removal by the GPTAD (Elastic Van Gieson stain).

Fig.4 Section of vein at the site of clot removal by the GPTAD. (Immunoperoxidase staining for type IV collagen).

Fig.5 Section of the middle part of the vein. (Immunoperoxidase staining for Type IV collagen).

Fig.6 Section of normal (the control) vein; no suction applied (Elastic Von Gieson stain).

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Fig.7 Section of normal (the control) vein; no suction applied. (Immunoperoxidase staining for type IV collagen).

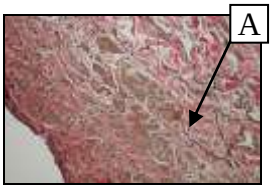

Fig.8 Section of middle part of vein. (Elastic Van Gieson stain).

DISCUSSION

Histological analysis of the sections taken from the vein wall indicated that there was no apparent intimal, medial or adventitial damage either on routine histological morphology or on special stains with Van Giesen and PAS staining. Type IV collagen immune-stains did not show any significant abnormality on the popliteal vein specimen. Although this is a pilot study (which will be extended) for this new device, we believe that the results indicate that the GPTAD could potentially be a useful device to use in blood clot removal in vessels.

CONCLUSIONS

From our study we conclude that the results are consistent with previous mathematical modelling indicating that the forces needed to extract a blood clot from a vessel wall are within the range used to extract a blood clot from the vein. This indicates that the GPTAD may therefore have potential use in the removal of blood clots in human vessels.

In addition, the Van Giesan stain, the PAS and immuno-stains all indicated that there was no histological damage apparent in the vein wall at the site of clot removal by the GPTAD, or at sites where direct sucking using pressures of 85kPa was applied.

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